Interaction of Marine Renewable Energy and Marine Organisms: Active Acoustic Assessment

Benjamin J Williamson[a,b], Shaun Fraser[a,b], Vladimir Nikora[b], Philippe Blondel[c], Ana Couto[b], James Chapman[b] and Beth E Scott[b]

a) University of the Highlands and Islands, UK; b) University of Aberdeen, UK; c) University of Bath, UK

Introduction

As of July 2019, there are 8.5 GW of UK offshore wind installed capacity, and the UK Government has estimated 20% of current UK electricity demand could be met with wave and tidal stream sources. Scotland is targeting the equivalent of 100% of gross annual electricity consumption from renewable sources by 2020, having achieved 74% as of 2018. However, with rapid development of marine renewable energy (MRE) including wind, wave and tidal stream energy devices, uncertainty remains surrounding the environmental and ecological effects of installing and operating devices and arrays[1]. Concerns include disruption of migratory and foraging behavior, direct mortality from animal collision with underwater turbines, attraction of animals to structures or to prey attracted to or aggregating around structures, or conversely displacement from preferred habitat[2].

Changes in behavior of fish species, in particular those which are common prey of seabirds and marine mammals, could lead to changes in foraging behavior of their predators as observed at offshore wind turbines[3]. Regulators, developers and operators need to understand the environmental effects of installing and operating devices and arrays in the marine environment.

Methods

The Flow, Water Column and Benthic Ecology (FLOWBEC) seabed platform integrates multiple instruments to concurrently monitor the physical and ecological environment in marine energy sites[4] (Figure 1). Onboard batteries and data storage provide continuous recording of a 14-day tidal cycle, and allow measurements to be taken adjacent to marine energy structures and in areas free from such devices[5]. Longer deployments are possible using triggering or duty-cycling of instruments.

Figure 1 – The FLOWBEC multi-instrument seabed platform.

An Imagenex 837B Delta T multibeam echosounder (260 kHz) sampling eight times per second to measure animal behavior is synchronized with an upward facing Simrad EK60 multifrequency (38, 120, 200 kHz) scientific echosounder sampling once per second to measure fish schools present[5]. A SonTek/YSI ADVOcean

5 MHz Acoustic Doppler Velocimeter (ADV) is used to measure mean flow and turbulence at a sampling frequency of either 16 or 20 Hz[6]. A WET Labs ECO FLNTUSB fluorometer measures chlorophyll-α concentration and turbidity. Field measurements are complemented with outputs from a 3D hydrodynamic model[7].

This study focuses on two consecutive deployments[5] of the FLOWBEC platform at the European Marine Energy Centre (EMEC) Fall of Warness tidal site in Orkney, Scotland (Figure 2). A deployment 22 m from the center of the Atlantis AK-1000 tidal turbine base is compared to a "reference" deployment, in similar conditions 424 m away in an area free from devices. The turbine support structure included a 10-m high piling, and three 4-m high ballast blocks; no nacelle or blades were present. For reference, the blades for the AK-1000 turbine were 18 m in diameter, with a rotor swept height of approximately 4.5-22.5 m above the seabed.

The two sites had comparable: depth of 35 m; flow speeds up to 4 m/s; substrate and topography verified by remotely operated vehicle (ROV) surveys; distance from shore; and natural hydrodynamic conditions verified by hydrodynamic model outputs and ADV measurements[4,6]. This minimized the effects of natural spatial variations and maximized spatial comparability, such that any difference observed between the two sites could be attributed to the presence/absence of the turbine structure. Deployments were back-to-back to maximize temporal comparability and to minimize changes in fish abundance or the relative abundance of different species over the period of deployments.

Fish schools were detected and discriminated from sources of interference, including backscatter relating to turbulence, using multifrequency EK60 data and the methods described in Fraser et al.[8]. This approach used adaptive processing to preserve sensitivity throughout the dynamic conditions, with multifrequency validation and manual inspection providing robust detection.

Fall of Warness Tidal Test Site
European Marine Energy Centre, Orkney, UK

● FoW1	■ FoW2
59° 8.99′ N, 2° 49.61′ W	59° 9.22′ N, 2° 49.56′ W
22 m from Atlantis turbine structure	Reference (no turbine structure)
2 Jun – 15 Jun 2013	18 Jun – 5 Jul 2013

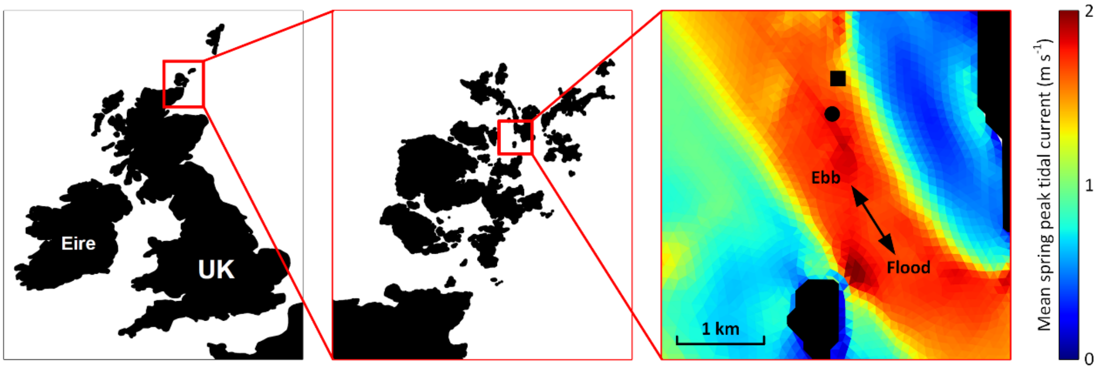

Figure 2 – Two deployments of the FLOWBEC platform were used to investigate the effects of a tidal turbine structure[5].

Schools were delineated and recorded with their mean height above the seabed. This study used fish school observed cross-sectional area as a measure of the size of a fish school. Differences in fish school vertical distributions are investigated for flow speeds above and below a nominal tidal turbine cut-in speed[9] of 1 m/s.

Results

The rate of schools and school area per hour increased by 1.74 and 1.75 times respectively around a turbine structure compared to observations under similar conditions without a turbine structure (Figure 4). The greatest increase in rate of 5.66-times higher occurrence of fish schools occurred at flow speeds below 1 m/s during the flood tide, when measurements were taken in the wake (downstream) of the turbine structure and compared to the same conditions without a turbine structure. The largest schools occurred at maximum flow speeds and the vertical distribution of schools over the ebb/flood and diel cycle was altered around the turbine structure[10].

Discussion

While the predictable attraction or aggregation of prey may increase prey availability and predator foraging efficiency, attraction of predators has the potential to increase animal collision risk. Quantifying the presence, vertical distribution and behavior of predators and prey can refine collision risk estimates with empirical data, including the changes to collision risk arising from predictable changes in fish (prey) behavior, presently a 'missing link' in collision risk modelling.

Predictable changes from the installation of turbine structures can also be used to estimate cumulative effects on predators at a population level. These techniques can guide a strategic approach to the monitoring and management of turbines and arrays through understanding of changes to habitat to support the sustainable development of marine renewable energy.

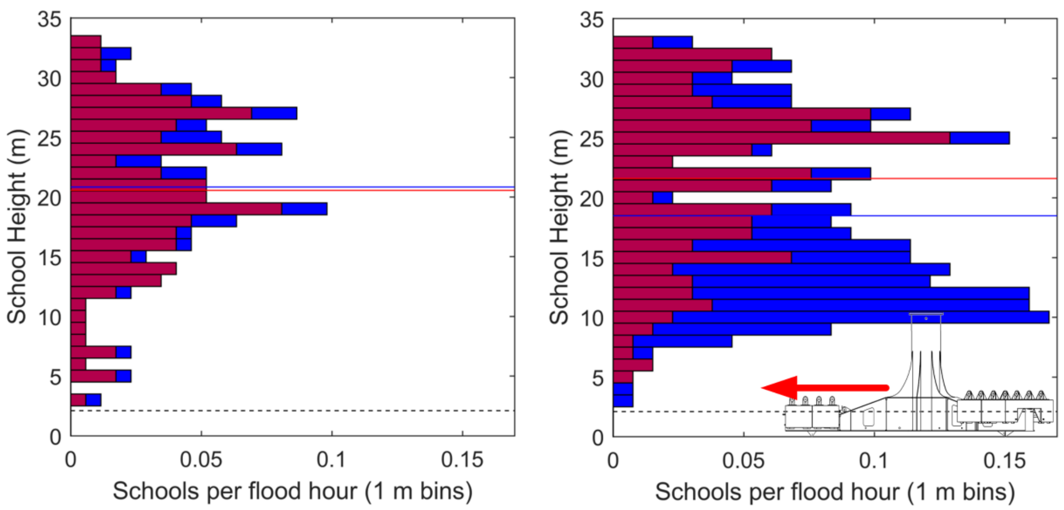

Figure 3 – The rate of fish schools increased in the wake of the turbine structure (right) compared to measurements without a turbine structure (left), both at speeds above (red bars) and below (blue bars) 1 m/s.

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